Analysis Activities

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1 Introduction

Two key activities in 1999, from an IGS Analysis point of view, were the LEO (Low Earth Orbiter) workshop and the 1999 Analysis Center workshop. The LEO workshop was held in Potsdam in March 1999. Although there are currently no operational LEO satellites which are equipped with a (usable) GPS receiver there are a relatively large number of missions planned in which LEO satellites will carry one (or more) GPS receivers. In general the GPS applications for LEO satellites can be divided in two groups; precise orbit determination (POD), and atmospheric sounding. Both types of LEO missions require rapid, if not real-time, and accurate orbits for the GPS satellites. In addition the atmospheric sounding missions will also require a very high data rate (few second sampling) from a GPS ground receiver network. Clearly the LEO missions have the potential to fundamentally change the IGS as we know it today. It is therefore necessary that the IGS takes an active role in this field if it does not want to loose its position as the service which delivers the reference system for all GPS applications.

The 1999 IGS Analysis Center workshop took place in June 1999 at the Scripps Institution of Oceanography in La Jolla, California. A summary of the workshop may be found in IGSMAIL #2359. The workshop dealt with two major topics; "real- and near-real-time products and applications" and "long-term stability and accuracy of GPS Reference Frame". The position paper "Moving IGS products towards real-time" by Gerd Gendt, Peng Fang, and Jim Zumberge, proposed the generation of both more rapid and frequent IGS products for (near-) real-time usage. These products, which will be delivered every 12 hours (two times per day), will contain a 48 hour orbit arc from which 24 hours are real orbit estimates and 24 hours are orbit predictions. The latency of this product is 3 hours. The first Analysis Center ultra rapid products were provided by GFZ by the end of October 1999. The generation of a combined "ultra rapid" product (IGU) has started in March 2000 based on contributions from up-to five different Analysis Centers.

	TX	TY	TZ	RX	RY	RZ	D
	mm	mm	mm	mas	mas	mas	ppb
Offset	0.3	0.5	-14.7	0.159	-0.263	-0.060	1.430
+/-	2.1	2.1	2.1	.090	.098	.088	.31
	dTX	dTY	dTZ	dRX	dRY	dRZ	dD
	mm/y	mm/y	mm/y	mas/y	mas/y	mas/y	ppb/y
Drift	-0.7	0.1	-1.9	0.013	-0.015	0.003	0.192
+/-	.3	.3	.3	.011	.012	.011	.043

Table 1: Transformation from IGS(ITRF96) to IGS(ITRF97) at epoch 1-AUG-1999. The IERS convention for the transformation parameters was followed. The equivalent changes in polar motion, in the sense (ITRF97 - ITRF96), may be obtained using PMx = RY and PMy = RX.

2 Change of Terrestrial Reference Frame (ITRF97)

As discussed and agreed upon during the Analysis Center workshop the IGS changed its realization of the International Terrestrial Reference Frame by switching from the ITRF96 to the ITRF97 on 1 August 1999 (GPS week 1021). At the same time the set of reference stations (RF) was slightly enhanced from 47 to 51 sites. The main change was the inclusion of a few sites for which the accuracy was insufficient in the ITRF96 but which are well determined in the ITRF97. A SINEX file containing the necessary information about these 51 reference stations may be found at the IGS Central Bureau. Although the ITRF96 and ITRF97 frames are nominally aligned globally in all 7 Helmert components and their rates, comparison of the IGS subset of RF sites shows significant differences between the ITRF96 and ITRF97 realizations. The expected differences between the IGS products based on the ITRF96 and ITRF97 reference frames are given in Table 1. More information about this ITRF change may be found in IGSMAIL #2432.

3 Current IGS and AC product quality

Despite the still rapidly increasing processing load due to more stations, additional products (ultra rapid!), and shortening submission delays, the Analysis Centers managed again to improve and/or maintain their solution precision, timeliness, and reliability. The quality improvement of the IGS products since 1994 is demonstrated in Figure 1, which shows the weighted orbit RMS (WRMS) for the final Analysis Center solutions with respect to the combined IGS final orbit products. Several Analysis Centers and also the IGS rapid orbit products have reached the

Year	COD	EMR	ESA	GFZ	JPL	NGS	SIO	IGR
1994	11	14	17	12	14	32	21	-
1995	8	10	14	10	9	17	16	-
1996	6	10	9	9	7	15	8	6
1997	4	10	7	6	6	16	7	5
1998	4	10	7	4	5	14	6	5
1999	3	10	7	3	4	9	5	4

Table 2: Yearly average weighted orbit RMS (cm) of the Analysis Center and IGS Rapid (IGR) orbit solutions with respect to the IGS final orbits.

Products Delay	Predicted Real-Time	Rapid 17 hours	Final 11 days	Units
Orbit	50.0	10.0	5.0	cm
Clock	150.0	0.5	0.3	ns
Pole		0.2	0.1	mas
LOD		30.0	20.0	μs/d
Stations			5.0	mm
Troposphere			4.0	mm ZPD
Geocenter			30.0	mm
Terrestrial Scale			2.0	ppb

Table 3: Quality of the IGS Reference Frame products at the start of the year 2000

3–4 centimeter orbit precision level. Similar levels of accuracy are indicated by the IGS 7-day arc orbit analysis and by comparisons with satellite laser ranging observations of the GPS satellites PRN 5 and 6. The enormous efforts and the resulting improvements of the Analysis Center global solutions are also shown in Table 2, where the yearly averages of weighted orbit RMS values are shown for all Analysis Centers and the IGS rapid orbit (IGR).

The primary objective of the IGS is to provide a Reference System for a wide variety of GPS applications. To fulfill this role the IGS produces a large number of different combined products which constitute the practical realization of the IGS Reference System. Table 3 gives an overview of the estimated quality of these different IGS Reference Frame products at the start of the year 2000.

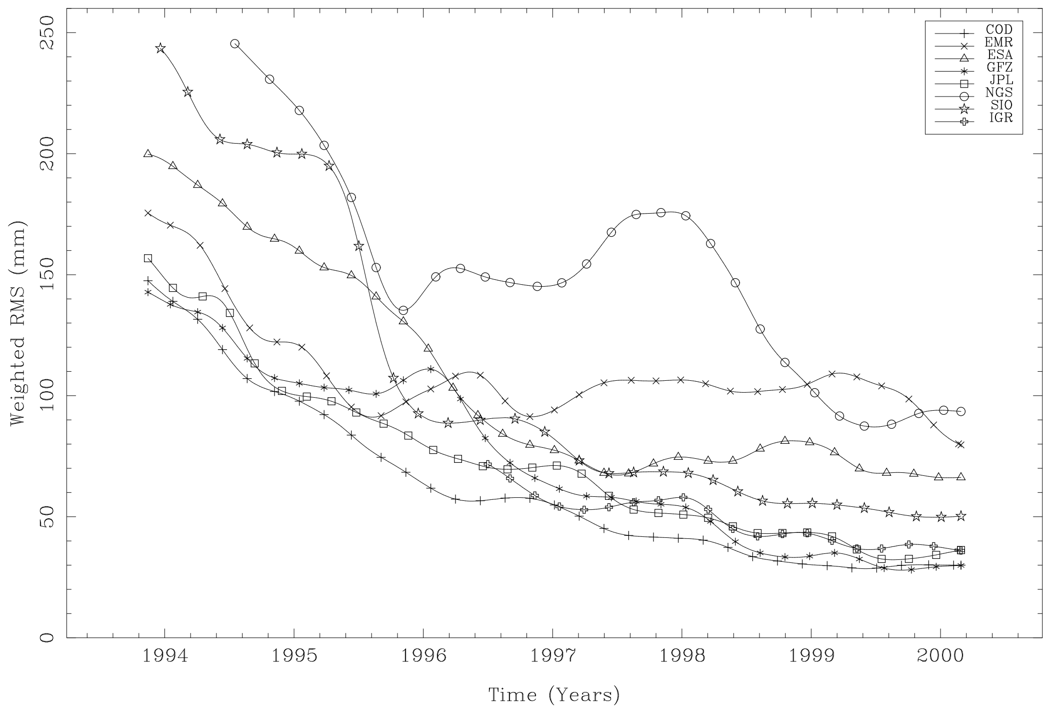

Figure 1: Weighted orbit RMS (mm) of the Analysis Center and IGS Rapid (IGR) orbit solutions with respect to the IGS final orbits. The weekly WRMS values from the orbit combination summaries were smoothed for plotting purposes, using a sliding 10 week window.

4 Outlook

As mentioned earlier a new, ultra rapid, IGS combined product (IGU) will become available in the near future. This product will be available for real-time usage, like the IGS predicted orbits (IGP), but the quality should be significantly better because the average age of the predictions is reduced from 36 to 9 hours. In the months to come, the quality and the reliability of the IGS Ultra rapid (IGU) orbits will be assessed against the IGS Predicted (IGP) and IGS Rapid (IGR) products. When it reaches a satisfactory level (which could be sooner than we think) the IGU products will replace the the IGP and IGR products.

A second, nearly completed, change is the new clock combination which is based on the RINEX clock format. This new clock combination will provide the normal combined satellite clocks in the orbit (SP3) format and it will also provide both satellite and station clocks in the RINEX clock format. These clock products will have a sampling rate of 5 minutes compared to the current 15 minutes. Some Analysis Centers even provide higher sampled clock products, e.g., JPL provides clocks with a sampling rate of 30 sec. This new clock combination is currently (March 2000) running in a test mode and preliminary results are being made available.

The plans for the new and improved IGS Reference Frame (RF) realization, as proposed during the 1997 Analysis Center workshop by Jan Kouba, have been finalized in March 2000. Starting with GPS week 1050 the weekly IGS RF realization, as generated at NRCan by Remi Ferland, has become official, see IGSMAIL #2740 for more details. In this new IGS RF realization the combined orbits are made consistent with the combined IGS Reference Frame (SINEX) solution by using both the transformation parameters and the combined ERPs stemming from the SINEX combination.